CARNOCHAN

ADDRESS ON THE STUDY OF SCIENCE

# ADDRESS

ON THE

# STUDY OF SCIENCE,

DELIVERED IN THE

NEW YORK MEDICAL COLLEGE,

AT THE

COMMENCEMENT OF THE WINTER SESSION,

OCTOBER 20, 1857.

BY

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NEW YORK MEDICAL COLLEGE,
*Oct.* 21*st*, 1857.

TO PROF. J. M. CARNOCHAN:

*Dear Sir :*

We have been appointed by a full Meeting of the Class in this College to solicit from you, for publication, a copy of the instructive Address, delivered by you last evening, as an Introductory to the Course in this Institution.

Hoping to receive from you a favorable response to this request, we remain, Very respectfully,

Yours,

S. DOWNER SCUDDER,
ELIJAH C. KINNEY,
WILLIAM J. BANER,
*Committee.*

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45 LAFAYETTE PLACE,
*Oct.* 22*d*, 1857.

GENTLEMEN:

I have received your note, asking, for publication, a copy of my Address, delivered at the opening of our Winter Session. I accede with much pleasure to your request. With best regards,

Very truly yours,

J. M. CARNOCHAN.

TO MESSRS. S. DOWNER SCUDDER,
ELIJAH C. KINNEY,
WILLIAM J. BANER,
*Committee.*

# ADDRESS.

"WHAT gave Marcellus the greatest concern," relates Plutarch, in his account of the storming of Syracuse, "was the unhappy fate of Archimedes, who was at that time in his museum, with his mind as well as his eyes so fixed and intent upon some geometrical figures, that he neither heard the noise of the Romans, nor perceived the city to be taken. In this depth of study and contemplation, a soldier came suddenly upon him, and commanded him to follow him to Marcellus; which he refusing to do, until he had finished his problem, the soldier in a rage drew his sword and ran him through." The studies, gentlemen, which enrapt the soul of Archimedes in the midst of war's alarms, must have been a source of pleasure, pure and high, not less valued than existence itself. With such men, the appetite for finding out laws from facts, causes from effects, necessary truths from the floating occurrences of the day, puts in its claim to gratification, which is as legitimate as that of the animal nature for food and sleep. If the question, "What fruit does science bring?"—be un-

derstood, as it certainly ought not, to refer to the *material* wants of humanity, it is a base and sordid question, against which every better mind indignantly protests. Science was never brought to its present height by hopes of wealth, plenty and comfort alone, but chiefly by those "admirable loves" with which she can inspire her followers. But, whilst the coldest utilitarians admit that the value of science must not be estimated by what she can practically perform, no doubt it must be granted that even the highest sciences do condescend to help our lowest wants. Astronomy, Chemistry, Geology, and Mechanics, not only furnish delightful contemplations to the student, but they put food into the mouths of the million: they clothe them, and fill their purses: they put houses over their heads, and adorn them with objects of beauty and convenience. The acquisition of knowledge is, indeed, in itself a positive good: the man who has his mind open to the perception of surround ing objects, and is led to reflect upon their nature and properties, has much greater capabilities of happiness—has much greater capacity for understanding and fulfilling the duties of his station, than if brought up in gross ignorance, without ever having exercised his intellectual powers. Besides attaining the self-denying, upright, benevolently co-operating and industrious habits, which live in the very atmosphere of science, an enlightened intellect looks after and before, observes relations, calculates consequences, and according to the nature of things, avoids evil and secures good. There is no situation in life that must

not, after all, owe its highest enjoyments to feelings with which the mind is connected: there is none which may not be cheered and refined from the same source. Independently of all worldly considerations, scientific pursuits always bestow rich rewards on their votary, in the delights attendant upon their cultivation, and the temporary oblivion, at least, of all care, in the abstraction they require. Finally, it may be said that while we have long experienced that knowledge is profitable, we are now beginning to find out that it is moral, and shall at last discover it to be religious. Aristotle declared the highest and truest science to be that which was most disinterested. Bacon, treating science as separate from religion, asserted knowledge to be power, and held that truth must be tested by its fruits, that is, its instrumentality in promoting the right and useful. Both assertions may be justified and reconciled by the fact, that, while no real knowledge is powerless and fruitless, the fruits differ in refinement and value; the highest being, unquestionably, those disinterested gratifications which minister to the highest wants and the highest faculties, and which earned for Philosophy the title of a "divine love," realizing the mysterious longing of the soul, and promoting the accomplishment of its destiny: "To rise in science as in bliss."

But, science confers these advantages only on condition that those who cultivate it shall be absolutely devoted to truth, and that far from seeking to maintain the error they may have mistaken for it, they shall be the first to renounce it, and incline their heads

to those who set them back in the right path. But is the acquisition of truth as easy as is commonly supposed? This question must be answered unhesitatingly in the negative. It will not suffice to declare that we are seekers after truth; we must be also able to say, that we know how to distinguish it from error, and that being able to demonstrate its reality, we are likewise able to develop its consequences. The hostility which well-intentioned men sometimes bear to the propagation of truth proceeds, in part, from a secret dread that one day all things may be explained—thus evincing the profoundest of all infidelity, the fear lest the truth be bad—and in part, from the belief that it is frequently the cause of those disturbances which threaten the existence of the social state. But truth should not be held responsible for the results of error. It is demonstrable that the evil effects we so frequently witness, proceed from erroneous opinions propagated as truths, and which would have been nipped in the bud, had they been submitted to a method of examination fitted to establish their falsehood; the greatest of all falsehoods being the pretension to understand and explain that which it is impossible for any human being to understand and explain. Thus, the ability of discriminating between what is true and what is false lies at the very threshold of the pursuit of science; and we acquire this ability by familiarizing the mind with the rules which constitute method. There exists a general method, and there also exist particular methods, adapted to the different branches of human science.

The rules of the general method are found in all the particular methods ; but, every particular method has special rules, which constitute the philosophy of the science to which they belong. To these special rules, we are indebted, from Galileo down to the present time, for the immense progress we have made in the natural sciences. In Astronomy, for instance, we take for our point of departure the observation of phenomena, and seek for their caus conformably to inductive rules which are appropriate to that science. The advantages of this direction of the human mind are no longer contested. We proceed from acquired truths to truths that are still latent, or in other words, from the known to the unknown, and thus the progress of knowledge is definitively assured.

But truth, the *magnum opus* of science—its possible achievement—the aim and object of the labors in which you are about to engage in these academic halls—where and how is it to be found ? This inquiry leads us directly to the consideration of the distinction of truths *a priori* and truths *a posteriori*, and of the methods which derive from them.

If there are any truths which the mind possesses, whether consciously or unconsciously, they may be called *a priori* truths, as belonging to it prior to all that it acquires from the world around. On the other hand, truths which are acquired from observation and experience, are called *a posteriori* truths; because they come to the mind after it has become acquainted with external facts. How far *a priori* truths are possible is the great battle-field of mental philosophy;

but, no one at present maintains that the mind can know anything at a point of time before its observation of external things began. However independent of experience any process may appear to be now, as for instance, that by which geometrical truths are proved, we may be sure that we made much use of observation before we educed the very laws which place it in our minds far above all need of confirmatory evidence from observation. A mind which never observed would not be mind. But the question is, whether even the facts which we observe do not furnish evidence that something was in the mind before it was directed to the facts; just as we know by looking at something, that we have eyes, and must have had them before we looked; although, without putting them to their common use, we could never have known that we had them at all. Now, without going into the dispute how much of our knowledge is *a priori*, we may be able to show that at least the conditions of all our knowledge are so—that the mind does not simply reflect the images of things without, but impresses characters of her own upon them—that our knowledge of things is not the exact counterpart of the things, but of the things and mind operating together. When we see our image in a mirror, we know that our shape is the cause of it, on the one hand, and the power of reflection in the mirror, on the other: if we were to see it multiplied, or increased, or diminished, or changed in hue, we should infer that the mirror had several angular faces, or was concave, or was convex, or made of tinted glass. Each

of these properties would be inherent in the mirror, *prior* to our presenting ourselves before it; they are its *a priori* laws, although we could only know them *a posteriori*, by a trial. When an image is received upon the mirror of the mind, we see that the latter, also, has its laws and properties. The mind does not simply receive the impressions of the senses; it groups them, judges about them, separates their qualities from each other, and draws inferences about the qualities which like objects, hitherto unknown, may be expected to have. But qualities, classes, inferences, are not objects of sense, however completely they may reside in or be drawn from these objects. They have no separate existence out of the mind; whilst, within it, they are perfectly distinct. This transmutation of objects of sense into their elements, must therefore be the work of the mind alone. It is a law of the intellect itself, and never was or could have been in the sensuous impressions we have received. The acts of the mind are so quick, so numerous, so complex, that they are not easy to note and describe, although we daily perform them, and that without serious mistakes. As the act of standing erect, so simple apparently, calls into operation a numerous array of muscles by means of which the body perpetually sways and adjusts itself without conscious effort, so we may believe that the mind goes through acts, which, from long practice, scarcely awaken her own attention, much less the sense of pain and effort; yet which involve a great number of subordinate acts, depending on distinct principles. When the English

traveler, Sir Francis Bond Head, was journeying across the Pampas of South America, his guide, one day, suddenly stopped him, and pointing high into the air, cried out: "A lion!" Surprised at such an exclamation, accompanied with such an act, the traveler turned up his eyes, and with difficulty perceived, at an immeasurable height, a flight of condors, soaring in circles in a particular spot. Beneath that spot, far out of sight of himself or guide, lay the carcass of a horse, and over that carcass, as the guide well knew, stood a lion, whom the condors were eying with envy, from their airy height. The signal of the birds was to the guide, what the sight of the lion, alone, would have been to the traveler—a full assurance of its existence. Here was an act of thought which cost the thinker no trouble, which was as easy to him as to cast his eyes upward. The sight of the condors convinced him that there was some carcass or other; but as they kept wheeling far above it, instead of swooping down to their feast, he guessed that some beast had anticipated them. Was it a dog or some other inferior animal? No. The condors would not fear to drive such away, or share with it. It must be some large beast, and as lions abounded in the neighborhood, he concluded that one was there. These steps, at least, of thought, and probably many more, rushed through his mind, and were summed up in the words: "A lion!"

From the primary conditions of thought—*a priori* and *a posteriori* truths, or in other words, mental action and experience—science is derived. In its

most comprehensive sense, it is defined to be a system of principles and deductions to explain some object-matter. To fulfil its intention, every science must have attained to true statements concerning its object-matter, so far as the nature of the case and the present means of examination allow: it must be able to define the object-matter and its several subordinate parts with clearness and precision: it must be able to indicate the extent of the domain the object-matter covers; and lastly, it must exhibit these results in a systematic and harmonious shape. For the first, it must employ Induction and Deduction: the second is the province of Definition: the third is provided for by Division; and the fourth may be referred to Plan.

The search after truth cannot long dispense with any one of these instruments; and even with the free use of them, the history of science shows how slow has been the advance, how largely the sand and mud of error have been mixed with the gold grains of truth. All of them, in their degree, have to do with evidence—with the proof of propositions: Induction and Deduction, chiefly with the discovery and appreciation of evidence: Definition, Division and Plan, chiefly with the statement and arrangement of its results. Hence, if we have to answer the question, whether a criterion of truth, that is to say, a standard for judging of the truth of propositions, is possible, the answer is, that evidence is the sole means of establishing, and therefore the sole standard for testing, the truth of any proposition, and that all the operations connected with evidence contribute their share to the criterion. In

fact, no shorter rule, no more portable touch-stone can be indicated than the whole science and rules of evidence. And in the special cases where other criteria appear to be applied—as in the discussion whether religious truth is to be tried by external testimony or internal conviction, whether historical evidence or the religious sentiment is the best criterion—the dispute is only as to the kind of evidence that shall take precedence.

Induction is usually defined to be the process of drawing a general law from a sufficient number of particular cases: Deduction is the converse process of proving that some property belongs to a particular case, from the consideration that it comes under a general law. More concisely, Induction is the process of discovering laws from facts, and causes from effects; and Deduction that of deriving facts from laws, and effects from their causes. For instance, that all bodies tend to fall towards the earth, is a truth which has been reached inductively, by considering a number of bodies where that tendency has been displayed: if from this general principle we argue that the stone we throw from our hand will show the same tendency, we deduce. If it were always possible duly to examine the whole of the cases to which a law applies, and to see by intuition the significance of each, the process of Induction would be simple enough. But a complete inspection of all the cases is very seldom possible. Even the laws on whose invariable operation the strongest reliance is placed, must have been laid down upon the evidence of a number of cases very

limited, when compared with the whole: that men must all die, and that heavy bodies tend to fall toward the earth, are statements which no one can boast of having verified by enumeration. The perfect certainty with which they are believed, rests upon far less than the millionth part of the cases that might be brought to bear witness about them. Nor, again, are the significant and essential circumstances easy to observe, in the few cases that lie within the reach. Either they escape notice altogether, as did the fact of the earth's revolution in the early days of Astronomy; or they are so entangled or overlaid with a mass of other facts, that their importance does not at first appear; like the action of cold in the production of dew, or the influence of an open drain in producing and sustaining fever. It appears, then, that the argument by which a law is laid down as the exact sum of all the single cases, will not suffice for scientific research. The statement, for instance, that all metals combine with oxygen, could not be formed until people discovered, what at first no one suspected, that oxygen was the cause of the rusting and tarnishing of metals: but, this is still open to dispute as an invariable truth; for, a metal which refuses to combine with oxygen may hereafter be discovered. Science, therefore, must employ other instruments beside this argument, so very limited in its application, so very liable to question.

In the first place it may be asked: How are the causes of facts to be distinguished among a multitude of other causes, all open to observation? To this the

answer is: By the principle of generalization. All men are apt to notice likenesses in the facts that come before them, and to group similar facts together. The similarities are sometimes so obvious that the most careless observer is arrested by them. The rise of the tide to-day and yesterday, the tendency to fall which a stone from the hand, an acorn from an oak, and a hailstone from a cloud, alike exhibit, and the power of growth exhibited by a grain of corn, afford groups of cases which seem so to classify themselves as to leave the mind little room for inquiry. The faculty by which such similarities are apprehended is called Observation: the act of grouping them together under a general statement, as when we say, "all seeds grow"—"all bodies fall," is Generalization; and from this principle follow some practical rules for ascertaining causes; such as:

The cause of a given effect *may be* the same as we know to produce a similar effect in another case better known to us.

For example, Berzelius records that a small bubble of the gas called seleniuretted hydrogen, inspired by accident through the nose, deprived him for some time of the sense of smell, and left a severe catarrh which lasted for fifteen days. An English etiologist suggests that the corresponding effects of influenza may be traceable to the same cause as undoubtedly produced them here—to the admixture, namely, of this or some similar substance with the air we breathe; and as a suggestion, this is perfectly legitimate, and may prove highly valuable.

Another rule is: If we can either find produced by nature, or produce designedly for ourselves, two instances which agree *exactly* in all but one particular, and differ in that one, its influence in producing the phenomenon, if it have any, *must* thereby be rendered sensible.

If that particular be present in one instance and wanting altogether in the other, the production or non-production of the phenomenon will decide whether it be or be not the only cause; still more evidently, if it be present *contrariwise* in the two cases, and the effect be thereby reversed. But, if its total presence or absence only produces a change in the *degree* or intensity of the phenomenon, we can then only conclude that it acts as a concurrent cause or condition, with some other, to be sought elsewhere. In nature, it is comparatively rare to find instances pointedly differing in one circumstance, and agreeing in every other; but whenever we call experiment to our aid, it is easy to produce them; and this is, in fact, the grand application of *experiments of inquiry* in physical researches. They become more valuable and their results clearer, in proportion as they possess this quality of agreeing in all their circumstances but one; since the question put to nature becomes thereby more pointed, and its action more decisive.

A third rule is: Complicated phenomena, in which several causes, concurring, opposing, or quite independent of each other, operate at once, so as to produce a compound effect, may be simplified, by subducting all the known causes, as well as the nature

of the case permits, and thus leaving, as it were, a residual phenomenon to be explained.

It is by this process, in fact, that science, in its present advanced state, is chiefly promoted. A very elegant example may be cited from the explanation of the phenomena of sound. The inquiry into the cause of sound had led to conclusions respecting its mode of propagation, from which its velocity in the air could be precisely calculated. The calculations were performed; but, when compared with the fact, though the agreement was sufficient to show the general correctness of the cause and mode of propagation assigned, the *whole* velocity could not be shown to arise from this theory. There was still a *residual* velocity to be accounted for. At length, Laplace struck on the happy idea that this might arise from the heat developed in the act of that condensation which necessarily takes place at every vibration by which sound is conveyed. The matter was submitted to exact calculation, and the result was at once the complete explanation of the residual phenomenon.

This is a specimen of the method according to which researches into causes are conducted. I add another example, exhibiting proportionality of cause and effect, experiment and residual phenomena, in one and the same set of inquiries.

In Sir Humphrey Davy's experiments upon the decomposition of water by galvanism, it was found, that, besides the two components of water, oxygen and hydrogen, an acid and an alkali were developed at the opposite poles of the battery. As the theory

of the analysis of water did not give reason to expect these products, they were a *residual phenomenon*, the cause of which was still to be found. Some chemists thought that electricity had the power of producing these substances of itself; and if their erroneous conjecture had been adopted, succeeding researches would have gone upon the false scent of considering galvanic electricity as a producing rather than a decomposing force. The happier insight of Davy conjectured that there might be some hidden cause of this portion of the effect; the glass vessel containing the water might suffer partial decomposition; or some foreign matter might be mingled with the water, and the acid and alkali disengaged from it, so that the water would have no share in their production. Assuming this, he proceeded to try whether the total removal of the cause would destroy the effect, or at least the diminution of it bring a corresponding change in the amount of effect produced. By the substitution of gold vessels for the glass, without any change in the effect, he at once determined that the glass was not the cause. Employing distilled water, he found a marked diminution of the quantity of acid and alkali evolved: still, there was enough to show that the cause, whatever it was, was still in operation. Impurity of the water was not the sole, but a concurrent cause. He now conceived that the perspiration from the hands touching the instruments might affect the case, as it would contain common salt, and an acid and an alkali would result from its decomposition under the agency of electricity. By carefully

avoiding such contact, he reduced the quantity of the products still further, until no more than slight traces of them were perceptible. What remained of the effect might be traceable to impurities of the atmosphere, decomposed by contact with the electrical apparatus. An experiment determined this: the battery was placed under an exhausted receiver, and, when thus secured from atmospheric influence, it no longer evolved the acid and alkali.

An example like this brings into strong light many of the characteristics of inductive reasoning. The later steps tend to confirm the earlier, on which, however, they themselves depend; so that a mutual confirmation is obtained from setting them together. When the chemist substituted gold vessels for the glass, and inferred, from the continuance of the effect under this change, that the glass could have nothing to do with its production, it was possible, in the existing state of knowledge, that the glass might be the cause, in one experiment, and the decomposition of the gold, in the other. But the later steps, which showed that the effect varied with the variations, in a circumstance wholly distinct from the decomposition of glass or gold, reduced the possibility of maintaining such a view to the lowest possible amount.

It may next be asked: How are causes discovered which are not obvious, even after repeated inspection of the facts in which they lie hid?

The answer is: By a power or combination of powers, granted only to a few, which has been called Anticipation; that is, the power of penetrating into

the secrets of nature, before the evidence is unfolded. It is enjoyed, as one might expect, by those only who have long and deeply studied the laws already laid open; but, not even by all of these. It is no mere power of guessing, but the power of an active imagination, supplied with materials by a clear understanding, carefully disciplined. The system of Anatomy, which immortalized the name of Oken, is the consequence of a flash of anticipation, which glanced through his mind, when he picked up, in a chance walk, the skull of a deer, bleached by the weather, and exclaimed: "It is a vertebral column!" When Newton saw the apple fall, the anticipatory question flashed into his mind: "Why do not the heavenly bodies fall like this apple?" In neither case, had accident any important share: Newton and Oken were both prepared by the deepest previous study to seize upon the facts offered to them, and to show how important they might become; and if the apple and the deer's skull had been wanting, some other falling body, or some other skull, would have touched the string so ready to vibrate. But, in each case, there was a great step of anticipation: Oken thought he saw the type of the whole skeleton in the single vertebra and its modifications; whilst Newton conceived, at once, that the whole universe was full of bodies tending to fall; two truths that can scarcely be said to be contained in the little occurrences, in connection with which they were first suggested.

The discovery of Goethe—which did for the vegetable kingdom what Oken's did for the animal—that the

parts of a plant are to be regarded as metamorphosed leaves, is an apparent exception to the necessity of discipline for invention; since it was the discovery of a poet in a region, to which, it was supposed, he had paid no special or laborious attention. But, Goethe was himself most anxious to rest the basis of this discovery upon his patient observation, and doubtless with good reason.

As with other great discoveries, hints had been given already, though not pursued, both of Goethe's and Oken's principles. Goethe left his to be followed up by others, and but for his great fame, perhaps, his name would never have been connected with it. Oken had amassed all the material necessary for the establishment of his theory: he was able at once to discover and conquer the new country.

A mistaken notion prevails that this rapid anticipation does not belong to the philosophic cast of mind; that it is precisely what Bacon condemns as the method which hurries rapidly from the particulars supplied by the senses to the most general axioms, and from them, as principles of indisputable truth, derives the intermediate axioms. It is thought that caution, and a deliberate examination of every particular we can find, before we allow ourselves to form any conclusion whatever, are the conditions of all sound physical inquiry. There is here a confusion of two distinct things: scrupulous caution should be exercised, before an hypothesis is considered to be proved; and the law we believe to be true, should be applied to every fact where it can be supposed to

operate, and to every other law with which it might interfere, in order to verify exactly what was at first only a happy conjecture. This manner of proceeding is well exemplified in the discovery, made by Professor Horace Green, of the use of the sponge-probang in the topical treatment of diseases of the respiratory passages; that is to say, there was first a genesis of the anticipation, which was then tested in every case where it could be supposed to operate. Bacon meant to complain that this sober process did not always follow the bright thought and brilliant suggestion; and perhaps, also, that the bright thought itself was not always suggested in the region of facts, but only of words. When the ancient astronomy, rushing to the general axiom, that "the circular motion is the most perfect," deduced from it the intermediate axiom, that the motion of the heavenly bodies must be circular, it might be reasonably charged with an abuse of anticipation; because the highest axiom, having no precise and definable meaning, cannot have really sprung from the contemplation of facts, nor do it and the axiom drawn from it square with the facts they pretend to embrace. But, on the other hand, when these conditions are obeyed, Anticipation is, as it has been called, the mother of scientific discovery. "To try wrong guesses," says an eminent physicist, "is with most persons the only way to hit upon right ones." The character of the true philosopher is not that he never conjectures hazardously, but that his conjectures are clearly conceived, and brought into rigid contact with facts. He sees and compares dis-

tinctly the ideas and the things—the relations of his notions to each other and to phenomena. Under these conditions, it is not only excusable but necessary, for him to snatch at every semblance of general rule—to try all promising forms of simplicity and symmetry. Anticipation, then, is the power whereby the mind presages a truth before it is fairly proved—before she proceeds to establish it by exact and cautious methods. Science works upon a system of credit: if she never advanced beyond her tangible capital, her wealth would not be so enormous as it is. She works with a principle as true, before she knows it to be so; because, in watching how it operates upon facts, consist the best means of establishing its truth; but, she must be prepared, at the same time, to abandon and dismiss it, whenever it is proved to be in direct and irreconcilable conflict with established facts.

Granting, on the one hand, that the theory or conception which anticipation furnishes to explain facts, will be worthless, unless it shall prove itself to be a fact, we must admit, on the other, that great steps of inductive discovery are made with the help of a preconception, and not by merely throwing observations together. That the fact of the elliptical motion of the planet Mars, was not merely the *sum* of the different observations, is plain from this: that other persons, and Kepler himself before his discovery, did not find it by adding together the observations. The fact of the elliptical orbit was not the sum of the observations merely: it was the sum of the observations,

seen *under a new point of view;* which point of view Kepler's mind supplied.

Such a conception effects the colligation, or binding together, of the facts to be explained. But, in order to connect itself with the facts, the conception itself must be capable of definition; not indeed of *adequate* definition—since we shall have to alter our description of it, from time to time, with the advance of knowledge—but still capable of a precise and clear explanation. For example, a large class of facts is bound together by the notion of chemical affinity, and could not be understood without the thread of the conception to run through them.

No rules can be given for the discovery of the appropriate conception that explains our facts; such achievements appear to result from a peculiar sagacity and felicity of mind—never without labor—never without preparation; yet with no constant dependence upon preparation, upon labor, or even entirely upon personal endowment. The suggestion of the conception may be due almost entirely to accident; the explanation of it, often by far the most difficult step, cannot be accidental, but will proceed from a natural sagacity, highly disciplined by scientific pursuits.

The variableness with which the power of conception manifests itself, is exemplified by what Goethe relates in his own case. "The quiet friend of nature," says that great man, "is not always in possession of himself; and from day to day, the subject is clear or obscure before his eyes, in proportion to the greater

or lesser activity of his intellectual powers. I shall make my subject more intelligible by a statement. Some time ago, I was occupied in reading manuscripts of the fifteenth century, which are full of abbreviations. Although I had never applied myself to the decyphering of manuscripts, I set to work with great energy, and to my astonishment, read off, without hesitation, unknown characters, which ought to have been riddles to me. My success was not lasting. Some time afterwards, when I wished to resume the same occupation, I found that I sought in vain to finish, by labor and attention, a task I had begun with spontaneous intelligence, rapidity and ease. I therefore resolved to await the return of those fortunate and fugitive inspirations."

If we may find such differences in our facility of reading old parchments, the letters of which are fixed, how must the difficulty be increased when we strive to guess the secrets of nature—that ever varying and coy nature, which hides from us the mystery of the life she bestows, sometimes unveiling what she had concealed, and at other times, concealing what she had only the moment before unveiled! What man can boast that he is gifted with the wisely measured sagacity, with the modest assurance which renders nature manageable at all times, and in all places?

Conceptions, not wholly correct, may serve, for a time, for the colligation of facts, and may guide us in researches which will end in a more exact colligation. The theory of the *circular* motion of the heavenly bodies was of this kind; and, in its turn, the concep-

tion of epicycles. The theory of phlogiston in chemistry made many facts intelligible, before the correcter one of oxydation superseded it. So with the theory of "nature abhors a vacuum," which served to bring together many cognate facts, not previously considered as related. An incorrect conception of this kind has a place in science, in so far as it is applicable to facts, and renders them intelligible. As soon as facts occur which it is inadequate to explain, we either correct it, or replace it by a new one.

Lastly, it may be asked, on what principle are incomplete inductions, or examinations of facts that stop short of complete enumeration, sufficient to establish general laws?

The answer is most important and interesting. All our experience teaches us that in the universe—the "Cosmos," whose very name means order—regularity and uniformity prevail, and caprice and uncertainty are excluded. Whilst it is conceivable that any one of the natural laws in which we have most confidence, might be reversed, our present belief in their persistence is almost unlimited. The thought that there might be no more daylight if our planet ceased to revolve, whilst one side of it was averted from the sun—that a draught from the spring could to-day destroy the life which it recruited yesterday—that a stone, thrown from the hand, could remain suspended in mid-air, instead of falling—never enters our minds, except perhaps as an amusing fancy; yet each of these things is possible. Whence, then, our confidence in the uniformity of natural laws? It is embodied in

the canon, that under the *same circumstances, and with the same substances, the same effects always result from the same causes.* But this great inductive principle is itself proved by induction, and partakes of the same defect that may be charged against inductive results; namely, that its terms are wider than our experience can warrant. Many groups of facts, connected as causes and effects, have not been examined; and in them, it is conceivable, at least, that there may be causes producing opposite effects at different times. If this were otherwise—if the canon were a simple enumeration of all the possible causes, its present value as a rule would disappear; since it is to the unknown and unexamined cases, that we chiefly wish to apply it. We draw a universal canon from an experience less than universal, and then employ it to justify us in drawing other universal truths from other particular experiences.

But here, the relation of deduction and induction, between synthesis and analysis, comes to our assistance. These pairs of terms correspond exactly, as names for the same two processes: but, induction and deduction give prominence to the law: analysis and synthesis, to the fact. Thus, we call the law of gravitation an inductive law, and speak of deductions from it; thinking more, in both cases, of the universal than of the particular cases it refers to. But, we analyze a fact or a substance, and make a synthesis—that is to say, a placing together of the elements to reproduce the fact or substance. Using the two former names, the law is made prominent; using the

two latter, we give prominence to the single fact. The supposed general principle may be tried by applying it to a new particular fact: the analysis of a fact into its elements may be tested by putting its elements together anew, and seeing if the fact is reproduced. And, such experiments offer a twofold advantage. If, on applying some general law, of which we are still uncertain, to a new particular case, we find that it helps to explain the particular, this is one fruit of the process; another is, that our confidence in the general law is materially strengthened. Law explains fact: fact confirms law. And, after this alternate ascent and descent has been a few times performed, our belief in the correctness of its results is quite complete.

This process can be most readily understood from an example. The metal called potassium was discovered in acting on potash by the voltaic battery. But a mind disciplined to scientific inquiry, saw, at once, that this single fact was an indication of a law. In the system of nature there is no caprice; if the power of yielding a metal belonged to this alkali, *as such*, beyond doubt other alkalies would participate in it. But the inductive argument is not strictly correct; for, we cannot argue from a single alkali to all alkalies, and the property we have discovered may belong to this alone, in connection with some undiscovered peculiarity. How shall this be ascertained? By trying how the conclusion, upon which suspicion rests, will apply to new facts; by experimenting upon another alkali, as if the law were already established;

by deducing from it, as we have induced into it. The experiment is tried and answers perfectly; and the success of the prediction operates strongly to raise our belief in the conclusion upon which it proceeded. That alkalies in general have a metallic base, was first indicated by one fact alone, that of potash; but the chemist was guided by that fact to a second experiment, and now a second fact strengthens his belief that a law exists. To extend the trials to the alkaline earths is suggested by their similarity to alkalies; with them, too, the experiments are successful, and the law is considered to be established.

Two principles, then, are arrived at: that the correctness of the synthesis is proportionate to that of the preceding analysis, and that a doubtful analysis may be confirmed by a synthesis. In other words, a correct induction furnishes the basis for a sound deduction, and a doubtful induction must be verified by deductions from it. Examples of this may be found on every side. The artillery-man, when he points a gun according to known rules, executes a synthesis of several laws—the law of gravitation, that of momentum, that of atmospheric resistance. If his shot misses, it will be either because some element has been left out of the analysis—the comparative force, perhaps, of different sorts of powder, or the windage of a loose ball in the barrel of the piece; or because the influence of each of the known laws has not been duly apportioned. The theory, that marble is carbonate of lime, fused under extreme pressure, has been made highly probable by the synthetic experi-

ments of Sir James Hall, who made a substance closely resembling marble by these means. A correct analysis of *lapis lazuli* was suspected to be erroneous; because there seemed to be nothing in the elements assigned to it, which were silica, alumina, soda, sulphur, and a trace of iron, to account for the brilliant blue color of the stone: accidental synthesis, which was followed up by intentional, reproduced it, and thus the analysis was found to be correct; whilst the synthesis is now daily performed for commercial purposes. The law, that the planets are retained in their orbits by an attractive force that varies inversely as the squares of their distances from the sun, was worked out to its theoretical results, and these were compared, synthetically, with the known facts. Theory was not found to correspond with fact, in all respects, and thus it became necessary to revise the analysis, and discover the residual causes that produced the variations; which astronomers succeeded in doing.

By the mutual co-operation of these two processes, the physical sciences are advanced. If no attempts were made to draw a conclusion, and see what use could be made of it, till complete grounds were before us, conclusions would never be drawn. The certainties by which the chemist, the astronomer, the geologist, conducts his operations with composure and success, were once bare possibilities, which, after being handed back and forward between induction and deduction, turned out to be truths.

A phenomenon strikes your senses: you observe it.

with the intention of discovering its cause, and to do so, you *suppose* one, to be verified by instituting an experiment. If the hypothesis be not founded, you make a new one, which you submit to a new experiment, and so proceed until your object is attained; that is to say, if the actual state of science will permit it. But to proceed in this manner, you must possess the scientific ability to institute experiments, and also the art of performing them with precision; for experiments verify an hypothesis only on condition that they have themselves been submitted to a series of experimental counter-tests, of such a character as to establish their correctness. Thus, then, ratiocination, inductive or deductive, suggested by the observation of phenomena, institutes experiments which enable us to assert the causes upon which the phenomena depend. This method of proceeding constitutes the experimental method; because, definitively, experiment is the test or criterion of the correctness of our ratiocination. The experimental method, thus defined, is applicable to the group of sciences, called sciences of observation and ratiocination. In some, the application has not been made; such as the sciences of geology, botany, and zoology, which are not now, whatever they may become hereafter, sciences of experiment, as well as of observation and ratiocination. It follows that a branch of human knowledge to which the experimental method has not been applied, has not as yet a complete scientific character. It may acquire it one day, but in the mean time, it cannot be taught with that degree of gravity and

luminous exposition which pertain to the sciences of higher development, such as chemistry and physiology. Medicine, also, including surgery, fulfils the three conditions of an advanced science; for, it observes, ratiocinates and experiments; observation being applied to the phenomena of disease; the ratiocination being for the most part inductive, and the experiment, the therapeutic treatment. Such, at least, is Rational Medicine. When the therapeutic treatment is not the experimental test of a ratiocination, but is, nevertheless, sanctioned by a certain amount of experience, medicine is empirical; but, when the treatment is wholly isolated, both from ratiocination and experience, medicine becomes quackery; of which immoral and opprobrious practice, this is a strict and adequate definition.

Scientific truth being the result of investigations made by the experimental method, there can be no sound instruction conveyed, which does not rest upon this method as a basis. For, the advantages and uses of true science are, that it consists not only in preventing error in regard to those things that are already known, but also in enabling the mind to distinguish what is true or probable from what must be erroneous, in respect of those things which are still involved in obscurity. In this latter case, patient and deep investigation becomes indispensable, and the habit of experiment, acquired in early life, will be efficient in putting the student upon the track which leads to the discovery of the unknown truth.

Of course, conjecture and hypothesis have their

use; but, if the conclusion which is derived from them be given as the expression of positive truth, it will produce all the bad effects of ascertained error, especially if it meet a certain direction of public sentiment or expectancy, at a certain epoch; for, then, opinions without any real foundation will receive from the theories, which are invoked in their support, a sort of consecration. We have only to cast our eyes abroad on the surface of society, to recognize the truth of this proposition.

The doctrine of progress, for instance, as defined and understood by many, is derived from theories, which have not been tested by experiment; consequently, it has conferred no advantage on society. Its influence is exercised in disparaging the past, and making light of the undeniable good which exists in the present—when its apostles do not claim to be the authors of that good. But, a doctrine of progress ought to be an exposition of the causes which have ameliorated society in its moral, material, and intellectual development, and such an exposition will be wanting in meaning, if, among other things, it has not for its object to make men feel how much they owe to the authors of that development. It embraces, therefore, an historical part, and, also, a moral part, the tendency of which should be to present the benefactors of humanity to our moral approbation. I need scarcely remind you that a prevalent idea of progress is directly the other way, and that its tendency is to extol the future, to the exclusion of the past and present. This tendency originates in ignorance or

dishonesty. In either case, it leads to error and injustice. We are not within the limits of truth in dating progress from the epoch in which we live. It begins with the origin of every community, and is so much the necessary consequence of the organization of man and of his specific nature, that we find it in every association that attaches itself to a particular soil and expands by successive generations. *Art is the nature of man.*

Let us examine, for a moment, what progress really is, and seek its causes by ascending to the past; that is to say, by following the inductive method as our safest guide. The cause of the most direct as well as the most lasting influence of the nations of antiquity upon the civilized nations of the actual world, was exercised by intellectual labors, with each of which the name of an individual is associated. Thus, religion had Moses for its exponent: poetry, Homer: history, Herodotus: philosophy, Plato: science, Archimedes. As regards religion, no influence is comparable to that of the people of Israel; while, as regards letters and the fine arts, none is comparable to that of the Greeks. But what part had the ancients in the cultivation of sciences? In pure mathematics, and even in mathematics applied to astronomy and mechanics, in cases where instruments are not required, ratiocination discovered a great number of truths. The discoveries of Euclid in elementary geometry, and of Archimedes in geometry and mechanics, place their authors in the first rank of intellectual power. The genius of antiquity reached, also, the highest point of elevation in

the treatment of those capital questions which are outside of pure mathematics, and of the sciences of observation, ratiocination and experiment. Whatever system of philosophy we may profess, Plato and Aristotle will always be men of the first order. In a word, antiquity showed immense power in the development of the method of deduction, when applied to speculative philosophy, and to the proof of propositions resulting from definitions, made in conformity with the laws of thought. Lastly, antiquity attained the extreme limits of the sublime and beautiful in poetry, architecture, sculpture, and, perhaps, in painting.

But, the aspect under which the ancients present themselves in the cultivation of the sciences of observation, ratiocination and experiment, is not equally brilliant. Here, their inferiority to the moderns is clearly manifest; but, while recognizing this inferiority, we must not imagine that it proceeded from inaptitude; for, the history of animals by Aristotle, testifies to the superior manner in which he was capable of handling questions, accessible to simple observation; and to what he might have accomplished, had he possessed instruments of the same precision as are employed at the present day. We might, also, refer to real experiments in physico-mechanics, performed by Pythagoras, when he showed the relation existing between the sounds rendered by chords and the weights which distend them.

The inferiority of the ancients in the sciences of observation, ratiocination and experiment, is to be attributed to many causes; but, the principal one was

the almost exclusive use they made of the *a priori* method. To this may be added the influence of the master upon the disciple; so great, for instance, in the school of Pythagoras, that it was only after many years of trial, the pupil was judged to be in a fit state to receive the first teachings of his master. Another cause of this inferiority was the tendency of the ancient mind to absolute opinions. For instance, so long as the magnet continued to be regarded in merely an absolute point of view, it was defined to be a body which had the property of attracting iron; but magnetism did not assume a scientific character, until the magnet came to be considered in a correlative point of view; that is to say, when it was seen that the bodies which act upon iron have two magnetic states; so that, if iron be attracted by the pole of a magnet, that part of the iron which is attracted has a different magnetic state from that of the pole of the magnet towards which it is drawn. It then became possible to define the magnetic property, by asserting that the bodies which manifest it are in two states. When they react, with their parts in the same state, there is repulsion; whilst there is attraction, when they react with their parts in different states. The magnetic property, considered in an absolute point of view, belongs to the infancy of science—an infancy which lasted for ages; whilst the definition of the two magnetic states, in the correlative point of view, is the conclusion of progressive science. The electrical properties of bodies, and chemical properties of the great-

est generality, occupy precisely the same position as magnetic properties.

The middle ages accepted submissively the teaching of antiquity, and under the sanction of the Roman theocracy, the authority of Aristotle was absolute in the schools. But, by degrees, out of the admixture of the nations which occupied the soil of Europe, arose a new civilization, and out of the multiplied relations of men holding a common faith, arose the sciences of observation, ratiocination, and experiment, to which we are indebted for a control and use of the forces of nature which neither antiquity nor the middle ages conceived to be possible. These sciences came into existence as soon as men became aware of the insufficiency of the *a priori* method to explain the most ordinary phenomena pertaining to natural philosophy. It is the glory of Bacon that he proclaimed the incompetence of the old method, and recommended experiment as the means of unfolding scientific truths.

Thus, the history of the human mind embraces two principal epochs; that which preceded the era of the experimental method, and that which, commencing with it, will endure so long as man shall desire to know the world in which he lives. But we cannot afford to sacrifice one of these epochs to the other, for we are equally their debtor: to the first, for its models of the sublime and beautiful in poetry, eloquence, historical narrative, architecture, sculpture, and philosophy: to the second, for its immense development of the natural sciences.

Such is progress, viewed in its greatest gener-

ality, and studied in its details by the light of the inductive method; that is to say, by ascending from effects to their causes, and thus reaching, in a measure, the cradle of human intelli gence. This manner of proceeding will enable us to perceive the slowness of progress, its prolonged struggles, and how little it owes to any one individual. For, however great may have been the performance of the discoverer, he in every case received vastly more from his precursors and cotemporaries than he has left to posterity. Is public opinion always conformable to this view of progress? Assuredly it is not. For instance, the majority of men are filled with extravagant wonder at such results as steam-locomotion and the electric telegraph, because they are ignorant of their antecedents; but the wise man, who is not ignorant of them, is moderate in his approbation, and declines joining in the acclamation of the multitude. Besides, men do not sufficiently consider the immense superiority of discoveries of laws of nature over mechanical invention, however ingenious. But Archimedes, himself one of the greatest inventors the world has ever seen, esteemed mechanical inventions greatly inferior in value to those speculations which carry irresistible conviction to the mind. Hans Christian Oersted used to call the year 1820 the happiest year of his life, because in that year he discovered *electro-magnetism*, or the law of reciprocity between electrified bodies and the magnet. "It was in the deep recesses, as it were, of a cell," says Sir John Herschel, "that in the midst of his study, a far idea first struck upon the mind of Oersted." He

waited long and calmly for the dawn which at length opened upon him, altering the whole relations of science, and, indeed, of life. The electric telegraph, and other mechanical inventions of recent date, are but mere effervescences from the surface of this deep recondite discovery, which Oersted liberated, and which was yet to burst with all its mighty force upon the world.

If men possessed science enough to be able to foresee, to some extent, at least, the consequences of a capital discovery, made by abstract science, they would never ask—*of what use is it?* and still less would they prostrate themselves before mechanical inventions, the merit of which is exaggerated by friends or interested judges. Better prepared to see consequences, in the one case, they would, in the other, be more capable of enlightened appreciation. While, also, they would be less astonished than they are by the practical results of great discoveries, made in the domain of nature, they would be enabled to see, in regard to those discoveries themselves, how small is the part of chance, how great the part of pure science. And in regard to utility, is it not because the Chinese despise abstract science, that their arts ceased in their development some centuries ago, and have not the progressive character, which the same arts exhibit among the nations of Christendom, owing to the marvelous influence exercised by the mathematics, physics, and chemistry? Thus, even in a purely moral point of view, it is evident that the more we are taught in our study of the law of progress, to ascend from effects to their causes, the greater will be

our respect for pure science, because we shall be more capable of appreciating its influence upon the condition of humanity.

An enlightened public will not believe in a complete man. It will never ask, who is the greatest poet: the greatest historian: the greatest painter. By this, we do not mean that the public, by becoming enlightened, will lose its admiration for men of talent—for those who occupy the first rank in letters, art, and science. On the contrary, being less absolute in its judgments, it will count many eminent men in the same department of human knowledge; and thus furnished with numerous objects for comparison, it will find new enjoyments of a highly rational kind, in observing the diversity of means employed by men of great gifts, in addressing the reason, the imagination, and the heart; and I may add, in observing the diversity of merit possessed by men, whose profession it is to alleviate the ills to which humanity is heir. Comparisons made in this spirit, without abasing the merit of one in proportion as we exalt the merit of another, have the advantage of satisfying the conscience that we are within the limits of truth; whilst, when the opinion we entertain is absolutely opposed to another, the result is to establish two categories of judges, one only of which has common sense—that, of course, to which we ourselves belong.

If a moderate amount of self-esteem be a beneficent provision of nature, it is equally true that the exaggeration of it is pernicious to the individual and to the society of which he is a member. The over-estimation

of one's own merit leads man to isolation. When he does not become hostile to the past, he despises it, or sees nothing in it deserving his respect; and as for his cotemporaries he does not like them, unless, indeed, they belong to the same sect as himself. Isolation fills him with unmeasured ambition for his own elevation at the expense of his fellow-men, for whom he has no care. It engenders an opposition to law and authority; an opposition which is based upon a false interpretation of the doctrine of progress. In fact, we find that numerous classes—in one conspicuous case, having an almost independent political status—denounce the actual condition of society, because, impressed with the successful applications of abstract science to the mechanical arts, they believe that society can be ameliorated with the same facility that matter is modified, when it obeys the commands of man, delivered from the sanctuary of science! These deceptive analogies between things really heterogeneous explain the sympathy felt for systems, which, although in contradiction with human nature, flatter our illusions, by promising what man cannot give, and which, therefore, it is unreasonable to hope for.

Now, is it not manifest, that whatever shows the weakness of the individual in the work of humanity, is a testimony to the power of association, a protest against the abuse of self-esteem, and a motive for uniting ourselves more closely than ever to our fellow-men? But it is precisely by means of the inductive method, applied to the study of progress, that the weakness of individual reason is demonstrated. It

points out the benefits of association, by showing that the greatest work of the greatest individual man could not have been performed, at a given epoch, without the assistance of his precursors and cotemporaries. In this relation, the history of the human mind, inductively considered, concurs with the Christian pulpit in attesting the weakness of man, even in his greatest triumphs.

I would, therefore, say to you: Admire the grand intellects that have existed in the past, and honor their memories for the advantages you have derived from them. And if you survey your cotemporaries, you will see many who are entitled to your admiration for their genius, and to your respect for their character. But, recollect, that this genial view of your fellow-men will chiefly depend upon the degree of cultivation you yourselves possess. *When a man's own mind is polished, it reflects the brilliancy of other minds; but, common people see no difference between man and man.*

THE END.

# ADDRESS

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